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North Marin County Water District, Novato, Calif

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Municipal Environmental Research
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Cincinnati OH 45268

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Beneficial Disposal of Water Purification Plant Sludges in Waste-Water Treatment

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This report discusses the advantages and disadvantages of the disposal of waste alum sludge from a water treatment plant to a municipal wastewater treatment plant and is submitted in fulfillment of Grant No. 803336-01 by Novato Sanitary District and North Marin County Water District with technical help from Culp, Wesner, and Culp. It covers the period from August 1974 to April 1977.

The study indicated no adverse effects on the sewage treatment process; however, solids loading to the digester was increased. BOD and COD removals were not affected; phosphorus removal was slightly improved. Settling characteristics of sludge in secondary clarification were improved.

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BENEFICIAL DISPOSAL OF WATER PURIFICATION PLANT SLUDGES IN WASTEWATER TREATMENT

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our national environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for preventing, treating, and managing wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for preserving and treating public drinking water supplies, and for minimizing the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research--a most vital communications link between the researcher and the user community.

Development of safe and economical methods for disposing of the sludges produced from wastewater treatment operations is one of the most pressing environmental needs. This publication provides much needed information on the feasibility of utilizing an integrated approach to municipal sewage sludge and solid waste disposal. This report describes a unique method for the disposal of sludge from a water treatment plant to a wastewater treatment plant.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

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1. Novato Sanitary District
2. North Marin County Water District
3. U. S. Environmental Protection Agency

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The cooperation and contributions of the management and staff of the districts, especially Mr. William I. Wilson of the North Marin County Water District, and Mr. Marvin J. Miller of the Novato Sanitary District, are gratefully acknowledged.

SECTION 1

INTRODUCTION

The objectives of this study were to determine on a plant-scale basis the beneficial and adverse effects and the costs of discharging water treatment process waste sludges into a sanitary sewer system, thence through the processes of an activated sludge sewage treatment plant. The work was carried out cooperatively by the Novato Sanitary District and the North Marin County Water District, both of Novato, California.

SECTION 2

SUMMARY OF FINDINGS

This study was conducted to determine the beneficial and adverse effects of discharging alum sludge from a municipal water clarification plant to a municipal wastewater treatment plant utilizing the activated sludge process.

Background data was collected in August through December, 1974 and in July and August, 1975. Data on the effects of alum sludge discharge was collected from September 9 through November 21, 1975 and May 14 through October 29, 1976.

The source of the alum sludge was the Stafford Water Treatment Plant operated by the North Marin County (California) Water District. The clarification-filter plant has a capacity of 6.2 mgd (million gallons per day)*. Alum sludge from settling basins and filter backwash was discharged to sanitary sewers which were a part of the collection system of the Novato Sanitary District. The Novato activated sludge plant had a capacity of 3 mgd.

Based on information collected during the study, the addition of alum sludge produced the following loadings on the wastewater treatment plant:

1. 0.25% more flow,

2. 23% more solids (dry basis) to the digesters,

3. 30% more solids to sludge dewatering and disposal facilities.

The study indicates the following changes due to addition of alum sludge:

1. The efficiency of primary settling decreased about 10%.

2. The efficiencies of COD (chemical oxygen demand) and BOD (biochemical oxygen demand) removals were not changed.

3. Phosphorus removal was improved about 12%.

4. Scum removal and sludge settling were improved in secondary clarification.

*For metric units see Conversion Factors at end of report.

5. The capacity of centrifuges for sludge dewatering was increased by a range of 12 to 50%.

6. Digester gas production increased beyond that attributable to the greater load of volatile solids applied, presumably due to improved mixing of digester contents.

7. Drying characteristics of dewatered sludge containing alum were not determined.

8. A slight improvement in final effluent turbidities was noted.

9. No adverse effects on overall wastewater treatment plant performance were observed.

SECTION 3

FACILITIES LOCATION AND OWNERSHIP

The facilities utilized in this study are the Stafford Water Treatment Plant owned and operated by the North Marin County Water District and the sewers and Novato Sewage Treatment Plant owned and operated by the Novato Sanitary District. Both organizations are public agencies but operate independently from other local agencies and each other. The facilities provide almost entirely domestic service to areas in and adjacent to the City of Novato, California.

STAFFORD WATER TREATMENT PLANT

Stafford Water Treatment Plant utilizes the water from Stafford Lake which derives its supply entirely from runoff from the adjacent 8.4 sq mi Novato Creek watershed. This supply currently provides approximately one-third of the domestic water requirement of the City of Novato service area. The remaining supply for Novato is obtained via pipeline from the Russian River, about 30 miles to the north of Novato.

The average annual runoff at Stafford Lake is about 4,900 acre-feet; however, output of the treatment plant has historically been restricted to the "safe yield" of the source of 2,000 acre-feet/yr. The historical mode of operation has been to utilize Stafford water throughout the year in proportion to demand. In the past few years, due to restricted Russian River pipeline capacity, the mode of operation has become increasingly a summer peaking operation using Stafford water at higher rates and for shorter periods during the high-demand summer season.

From the time the Stafford system was constructed until about the time application for this grant study was submitted, the treatment plant capacity was 4 mgd, and normal operating rates varied from 2.0 to 3.5 mgd. In order to accomodate the need for additional summer peaking capacity, an expansion project was completed in the spring of 1974 which increased plant capacity to 6.3 mgd. Since that time, the plant has been operated at rates from 2.0 to 6.3 mgd.

In addition to increasing capacity, the expansion project encompassed process modifications that materially altered the nature of the sludge produced, the most significant being that lime is no longer fed in the sedimentation basin. The current water treatment process is as follows (refer to Figure 1): raw water enters the plant and is chlorinated to excess of breakpoint. Alum is added at the inlet to the sedimentation basin and recirculated sludge flow downward in the center mixing chamber, then the

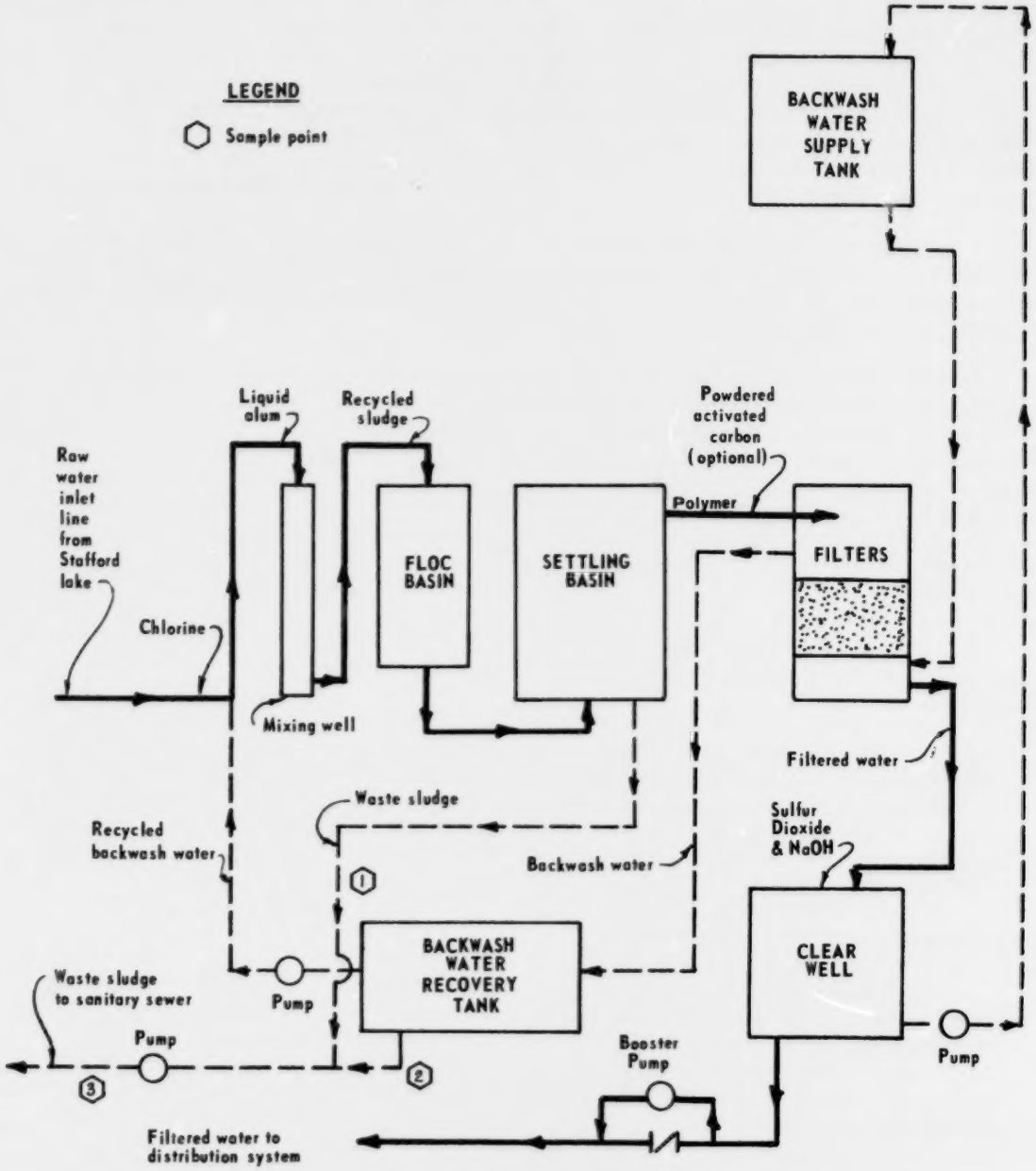

Figure 1. Schematic diagram of water treatment process
North Marin County Water District

clarified water flows upward in the outer clarifier chamber to overflow weirs. In the expansion project, plastic tube settlers were installed in the upper area of the clarifier to increase the allowable flow-through rate. Polymer is added as a filtration aid in the inlet channel to the four mixed media filters. Occasionally, granulated activated carbon is added at the filters to combat taste and odor problems. Filtered water enters a storage well, where sodium hydroxide is added to adjust pH and sulphur dioxide is added to neutralize excess chlorine. The finished water then flows by gravity, or is pumped, to the distribution system.

The waste materials produced in the treatment process include the sludge accumulated in the sdeimentation basin and the waste backwash water from cleaning of the filters. The material of greatest significance to this study is the WTP sedimentation basin sludge.

The solids content of the WTP backwash water also is of significance, since occasionally it must be disposed of to waste. Supernatant backwash water is normally pumped back to the sedimentation basin, but sludge (estimated to be about 2,000 gal/month) collects on the bottom of the recovery pond and must be disposed of at monthly intervals. In addition, under relatively rare conditions of extremely difficult to treat lake water quality, it is desirable to discontinue backwash water recycle and recovery within the water plant and to waste all backwash water and sludge for a period of time to straighten out the treatment process. This tactic has been employed possibly three times in the 23 year operating history of the WTP, including during the problem period of 1975. No backwash water or sludge was discharged to the sewers prior to this study.

Until 1972, plant wastes were disposed of by discharging to Novato Creek below the WTP. Since that time, WTP sludge has been disposed of by spray irrigation on the hillside above the plant. Some problems have been experienced with the spraying operation but in general it has been a satisfactory method. The spray facilities are kept operable so that discharge to the sewer system can be interrupted as may be required by the Sanitary District.

SANITARY DISTRICT FACILITIES

The water treatment sludge discharges to the sanitary sewer system approximately 4.5 sewer miles from the Novato sewer treatment plant. (Travel time of the sludge in the sewer system as determined by test is about two hours.) The Novato sewage treatment plant serves approximately 65% of the Novato service area. It has a current design capacity of 3 mgd and an average dry weather flow of 2.5 mgd.

The current sewage treatment process is as follows (refer to Figure 2): raw sewage and septic tank dumpings are pumped through the influent pump station to the primary clarifier. From the primary clarifier, part of the flow circulates through the biofilter, then back through the primary clarifier. The remaining flow and that recirculated after cycling through the biofilter passes to the hydraulic jump aerators (not currently in use),

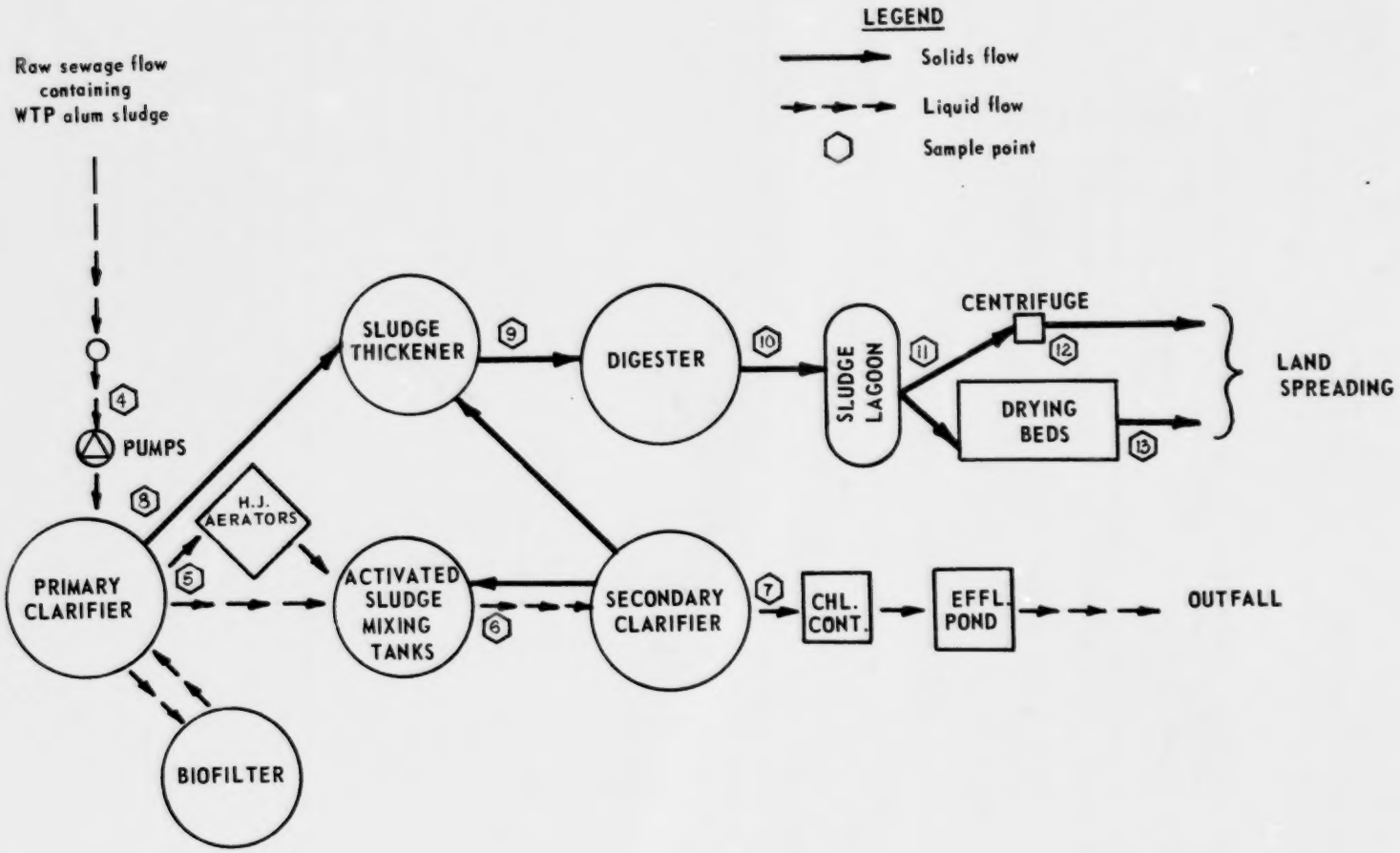

Figure 2. Schematic diagram of wastewater treatment processes Novato Sanitary District

then on to the activated sludge aeration tanks. Either aeration tank may be used alone, or they can be operated in series or in parallel. Effluent from the activated sludge tanks goes to the secondary clarifier, then to the chlorine contact pond, then to the effluent pond, then on out the outfall.

Primary clarifier sludge goes first to the sludge thickener. Part of the secondary clarifier sludge is recirculated to the aeration tanks, and the remaining excess goes to the sludge thickener. From the sludge thickener, sludge is pumped to the digester and dewatered by centrifuging or by drying in drying beds. Dewatered sludge is either spread directly on adjacent fields or is sorted on the premises for subsequent spreading.

Supernatant from the sludge lagoon is recirculated back to the raw sewage. Scum skimmed from the primary and secondary clarifiers goes directly to the digester.

MODE OF COOPERATION BETWEEN THE TWO PLANTS

The original approach to accomplish study objectives was to construct the facilities required to deliver the water treatment sludge to the sewer system, to conduct a comprehensive sampling and testing program at pertinent process locations (a) for three months prior to discharge of water treatment sludge to the sewage system, and (b) for two months subsequently during discharge of water treatment sludge to the sewer system. Then, to analyze and evaluate the sample and other pertinent data and write a report on the study and findings relative to the above stated objectives. The entire study was to be completed within one year. The initial grant authorization was for the period August 12, 1974 to August 11, 1975.

The initial pre-testing program was conducted during the period August through December, 1974. An additional sludge dewatering background testing program was conducted in July and August, 1975. Discharge of WTP (water treatment plant) sludge was delayed by major process modifications in progress at both the WTP and the STP (sewage treatment plant), delays in construction of the system for WTP sludge discharge to the sewer, and the need to do additional background testing. Discharge to the sewer system and additional sampling and testing were conducted from September 9 through November 21, 1975, and from May 14, 1976 through October 29, 1976.

Previously, the manager of the Novato Sanitary District had requested a change in plan to extend the study to encompass two periods of WTP sludge discharge during the summer of 1975 and again through the summer of 1976. (It was not believed that winter testing would provide meaningful data, due to high infiltration in the sewage system. Also, the WTP is shut down most of the winter.) Preliminary evaluation and report would be made at the end of the first full cycle of testing, then any needed adjustments would be made in the second cycle and a final report written upon completion of the second cycle. This plan was agreed to by the other parties concerned and EPA subsequently issued a Grant Amendment changing the project period to August 11, 1974 through April 11, 1977.

For purposes of the Grant, the study is now complete, and the results are reported herein. The Water District and the Sanitary District will continue work on their own on certain aspects of the study, principally on those items which bear on proper charges for acceptance and processing of the alum sludge from the water treatment plant at the wastewater treatment plant.

SECTION 4

MONITORING, SAMPLING, AND TESTING PROGRAM

DATA ON PRODUCTION OF POTABLE WATER AND ALUM SLUDGE

Tables 1, 2, and 3 contain information on WTP production of potable water and alum sludges. Table 1 summarizes data prior to WTP expansion. Table 2 shows the data after WTP expansion. The volume data for early 1975 are not representative of normal conditions, due to problems that were being experienced with the polymer being used as a filter aid, and unusually difficult raw water quality conditions. Table 3 presents data on annual production of alum sludge and potable water under 1976 normal, and maximum operating conditions at the Stafford Water Treatment Plant.

PRE-DISCHARGE TESTING

In order to determine the effects of the discharge of alum sludge from the water treatment plant upon wastewater treatment plant operations, it was necessary to collect background data at the wastewater treatment plant prior to discharge of alum sludge. This was done for a total of nine months in 1974, 1975, and 1976. Sampling points for liquid processing are shown on Figures 1 and 2.

Pre-discharge testing of solids thickening, digestion, and dewatering at the wastewater treatment plant was also conducted over a nine-month period in 1974, 1975, and 1976.

TESTING DURING DISCHARGE OF ALUM SLUDGE

Alum sludge was discharged to the wastewater treatment plant for a period of about six months in 1975 and 1976. Additional liquids and solids testing was done at this time.

The testing program is detailed in Table 4.

In January, 1976, testing of the effects of the WTP sludge on the centrifuge dewatering process was undertaken. Removal of STP sludge from the sludge lagoon is a batch process: it typically takes approximately six months with STP sludge only to fill the lagoon with digested sludge. The lagoon had been emptied prior to commencement of discharge of WTP sludge on September 9 and was not full when discharge ceased. When it filled in January, it had taken just four months to fill and the lagoon contained about 32% sludge containing WTP sludge. Ordinarily, this batch would have been disposed of by dumping it directly on the drying beds which is much

Table 1. STAFFORD WTP SLUDGE DATA SUMMARY BEFORE WTP EXPANSION

		1972		1973		
		October	November	March	April	May
Sludge volume, gal/day	Range	5,300-13,400	11,000-14,400	7,600-17,800	9,200-18,500	0-15,000
	Mean	9,700	12,600	11,000	13,700	11,300
Sludge solids, %						
	Range	1.03-2.16	-	0.4-1.49	0.59-1.49	0.54-1.20
	Mean	1.45	0.36	1.16	0.85	0.91
Daily plant output, mg	Range	1.58-2.27	1.74-2.20	1.7-2.01	1.53-2.07	1.71-3.79
	Mean	1.97	2.06	1.83	1.86	2.64
No of days of plant operation		25.4	12.3	30.2	28.3	30.3

Table 2. STAFFORD WTP SLUDGE DATA SUMMARY AFTER WTP EXPANSION

Month	Daily sludge volume, gal		% Solids in sludge	% Volatile in solids	Daily plant output, M.G.		No. days plant op.
	Range	Mean			Range	Mean	
JUNE, 1974	1,700-22,700	10,600			2.96-4.21	3.71	30
JULY, 1974	1,400-37,500	8,900			2.40-5.06	4.19	31
AUG., 1974	2,200-16,100	5,500			1.44-4.23	3.02	30
SEPT., 1974	2,000-20,200	3,400			2.37-3.27	2.69	29
OCT., 1974	1,800- 8,200	3,000			2.13-2.74	2.36	30
NOV., 1974	3,800- 8,600	2,300			1.25-2.42	2.18	15
APR., 1975	6,600-37,000	12,400			0.67-1.51	1.32	24
MAY, 1975	6,100-62,500	24,800			1.08-6.27	3.36	31
JUNE, 1975	10,900-69,600	34,200			2.69-6.40	4.67	30
JULY, 1975	6,200-98,200	17,100			2.13-5.97	3.54	31
AUG., 1975	4,700-28,900	11,800			2.97-5.99	3.61	31
DISCHARGE TO SEWER 9/5/75 TO 11/26/75 AND 7/17/76 TO 10/29/76							
SEPT., 1975	4,100-16,900	7,900	1.62	23.5	0.39-3.41	2.79	29
OCT., 1975	8,100-11,700	6,700	1.58	17.6	0.39-3.01	2.37	12
NOV., 1975	4,300-14,000	9,700	0.99	22.2		2.29	21
MAY, 1976	7,600-20,800	13,100				2.24	19
JUNE, 1976	1,300-73,000	22,200	0.63	27.9		3.59	30
JULY, 1976	3,300-12,100	7,100	2.31	19.9		3.59	15/16
AUG., 1976	600-46,400	5,900	5.52	17.6		2.33	31
SEPT., 1976	1,600-16,700	8,600	2.41	20.5		2.48	30
OCT., 1976	3,400-15,000	9,200	2.66	17.1		2.95	29

Table 3. STAFFORD WATER TREATMENT PLANT ANNUAL PRODUCTION OF ALUM SLUDGE AND POTABLE WATER

Month	1976			Normal			Maximum		
	Water output, acre-ft	Sludge, gal	Solids, lb	Water output, acre-ft	Sludge, gal	Solids, lb	Water output acre-ft	Sludge, gal	Solids, lb
JAN	0	-	-	0	-	-	400	800,000	168,000
FEB	0	-	-	0	-	-	400	800,000	134,400
MAR	0	-	-	120	240,000	30,000	400	800,000	100,800
APR	0	-	-	180	432,000	36,300	400	960,000	80,600
MAY	129	250,000	21,000	250	800,000	67,200	400	1,280,000	107,500
JUNE	326	665,000	34,100	300	600,000	50,400	400	800,000	67,200
JULY	326	299,000	61,500	300	270,000	56,700	400	360,000	75,600
AUG	212	126,000	63,500	300	180,000	75,600	400	240,000	100,800
SEPT	225	257,000	62,600	250	225,000	47,300	400	360,000	75,600
OCT	259	266,000	60,300	180	162,000	20,400	200	180,000	22,700
NOV	0	-	-	120	108,000	13,600	200	180,000	22,700
DEC	0	-	-	0	-	-	-	-	-
Total	1,477	1,863,000	303,000	2,000	3,017,000	397,500	4,000	6,760,000	955,900

TABLE 4. SUMMARY OF DATA COLLECTED DURING DISCHARGE OF WTP SLUDGE TO SEWER

*Loc Ref	Test description	Background testing: Type and frequency	Background testing: No. of samples	Background testing: Test period	Discharge testing: Test period #1	Discharge testing: Test period #2
1	WTP sed. basin sludge discharge record - volume flow, discharge periods	Continuous	--	June 1974 on	Fall 1975	Summer 1976
	Solids data - total, volatile, fixed, settleable; settleable supernatant-suspended solids, volatile solids, COD	Composite twice weekly	--	Jan Feb 1976	Fall 1975	Summer 1976
2	WTP washwater recovery pond residue					
	Discharge record, as above		--		None	Summer 1976
	Solids data, as above		--		None	Summer 1976
3	Sewer inspection for deposition	Visual check	1	Fall 1974	None	Summer 1976
4	STP influent					
	Suspended solids, settleable solids, pH, BOD	Composite twice monthly	17	Fall 1974 Nov Dec 1975 Jan Feb 1976	Fall 1975	Summer 1976
	Flow record	Continuous	--		Fall 1975	Summer 1976
	COD and PO_4	mo. comp.	4	12/74, 1/76 2/76	Fall 1975	Summer 1976
5	SPT primary clarifier effl. suspended solids, pH, BOD	Composite twice weekly	36	Fall 1974 Jan Feb 1976	Fall 1975	Summer 1976
7	STP final effluent COD and PO_4	Composite monthly	12	Dec 1974 Nov Dec 1975 Jan Feb 1976	Fall 1975	Summer 1976
8	STP primary sludge Total solids, pH, volatile solids	Grab, twice weekly	49	Fall 1974 11/75, 2/76	Fall 1975	Summer 1976
	Flow record	Continuous	--		Continuous	
9	STP thickener effluent Total solids, pH, volatile solids	Grab, twice weekly	49	Fall 1974	Fall 1975	Summer 1976
	Flow record	Continuous			Continuous	
10	STP primary digester effl. Total solids, pH, alkalinity, volatile acids, volatile solids	Grab, twice weekly	49	Fall 1974 12/75, 2/76	Fall 1975	Summer 1976
	Flow record	Continuous		Plant record	Continuous	
	Gas production			Plant record	Continuous	
11	STP sludge lagoon effluent appearance, consistency, pumpability	Visual		July Aug 1975 Summer 1976	Winter 1975	Fall 1976
12	STP sludge centrifuge effl. gen. characteristics	Grab, various		July Aug 1975 Summer 1976	Winter 1975	Fall 1976
13	STP sludge drying bed effl. appearance, consistency, removability			None	None	None

* For location of sampling points, see Figure 2.

cheaper than centrifuging. However, to see what effects the partial load of WTP sludge had, centrifuging was conducted for a short while.

TEST PROGRAM OBSERVATIONS

Factors under evaluation in the test program include the effects of receiving alum sludge from the water treatment plant at the wastewater treatment plant on:

1. Efficiency of primary settling
2. Efficiency of COD removal
3. Efficiency of phosphorus removal
4. Increased sludge production
5. Handling and dewatering characteristics of waste sludge
6. Overall wastewater treatment plant performance
7. Charges for processing alum sludge

Table 5 presents a summarized comparison of the results of wastewater treatment plant operation with and without the addition of alum sludge discharged from the water treatment plant. Table 5 gives the average values for all background data and average values for all data during alum sludge discharge.

Table 6 provides two comparisons of sludge data with and without alum sludge.

TABLE 5. COMPARISON OF AVERAGE RESULTS OF WASTEWATER TREATMENT PLANT OPERATION WITH AND WITHOUT ADDITION OF WATER TREATMENT PLANT SLUDGE

	Background data	Discharge data
INFLUENT		
Flow, mgd	2.46	2.21
BOD, mg/l	199	297
COD, mg/l	560	858
PO_4, mg/l	5.6	9.0
SS, mg/l	257	369
pH	7.06	7.2
PRIMARY EFFLUENT		
BOD, mg/l	113	114
SS, mg/l	101	112
pH	7.4	7.3
FINAL EFFLUENT		
COD, mg/l	99	98
PO_4, mg/l	4.5	4.0

TABLE 6. SLUDGE THICKENING AND DIGESTION WITH AND WITHOUT ALUM SLUDGE

	Background data		Discharge data	
	1974	1975	1975-76	1976
PRIMARY SLUDGE				
T.S., %	0.07	0.26	0.84	0.54
V.S., %	60.0	62.2	59.4	50.6
pH	7.6	7.3	7.3	7.1
THICKENER SLUDGE				
G.P.D.	14,448	14,175	22,670	27,509
T.S., %	3.26	3.89	2.81	2.89
V.S., %	81.5	81.5	66.1	61.9
pH	6.13	6.0	6.18	6.0
PRIMARY DIGESTER				
T.S., %	1.20	1.61	1.54	1.75
V.S., %	79.2	61.0	59.0	50.7
pH	7.23	7.22	7.23	7.06
Alkalinity, mg/l	3,310	3,681	2,118	2,761
Volatile Acids, mg/l	244	265	196	210

SECTION 5

RESULTS

Test results and observations during the course of the project indicate the following:

EFFICIENCY OF PRIMARY SETTLING

For all of the background (no alum sludge discharge) data collected, the average SS (suspended solids) concentration in primary effluent was 101 mg/l. When alum sludge was entering the wastewater treatment plant, the average SS content (excluding atypical readings) in primary effluent was 112 mg/l. Thus, the clarity of primary effluent was slightly better without addition of alum sludge as measured by the SS test.

EFFICIENCY OF COD REMOVAL

Plant effluent COD values with and without alum sludge addition averaged 99 and 98 mg/l respectively. Thus, the COD value during alum sludge addition was unchanged.

EFFICIENCY OF PHOSPHORUS REMOVAL

Average phosphate concentrations in plant effluent during background testing was 4.5 mg/l and during the test period with alum sludge addition was 4.0 mg/l. There appeared to be a slight benefit in phosphorus removal from alum sludge addition.

INCREASED SLUDGE PRODUCTION

The data from water treatment plant operations which are most applicable to estimating quantities of alum sludge to be discharged to the wastewater treatment plant are the figures collected since the revised and expanded water treatment plant was placed into operation in June, 1974, which are (see Table 2):

	WATER TREATMENT PLANT
Mean daily sludge volume, gallons	11,770.
Sludge, percent solids	2.35
Sludge, percent volatile solids	17.6
Dry solids, mean pounds per day	2,304.
Operation of WTP, days per year	194.
Sludge volume, million gallons/year	2.28
Dry solids, tons/year	223.

Background information collected at the wastewater treatment plant between 7-30-74 and 2-18-76 follows:

WASTEWATER TREATMENT PLANT	
Plant flow, average, mgd	2.46
Plant flow, million gallons per year	909.
Average SS, mg/l	257
Average SS, lbs/mg	2,141.
Average SS, tons/year (dry basis)	977.

Based on the above figures, on an annual basis the discharge of alum sludge to the wastewater treatment plant will increase the solids (dry basis) to the digester by 223 ÷ 977 = 23%, and will increase the flow requiring secondary treatment by 2.28 ÷ 909 = 0.25%.

Following digestion, the relative contribution of solids to dewatering and disposal by the WTP and WWTP differ from the figures given above for digester influent because of the higher content of non-volatile solids in the WTP alum sludge. From the data, the volatile solids in the WTP and WWTP sludges are 21% and about 61 respectively. If a 50% average reduction in volatile solids in each case occurs during anaerobic digestion, then the discharge of alum sludge to the WWTP will increase the dry solids to dewatering and disposal by: 223 (1.00-.5x.21) ÷ 977 (1.00-.5x.61) = 223 x .895 ÷ 977 x .695 = 200 ÷ 679 = 29.4%.

In summary, based on this preliminary information, it appears that alum sludge discharge to the WWTP increases:

1. Hydraulic flow through the primary and secondary liquid treatment processes by 0.25%,

2. Solids to the anaerobic digesters by 23% (dry basis), and

3. Solids to the lagoon sludge dewatering, and disposal facilities by 29.5% (dry basis).

As percentages of the total increased load, the figures are 0.25%, 18.5%, and 22.8% respectively. 2.28 ÷ 2.28 + 909 = 0.25%: 223 ÷ 223 + 977 = 18.6%: and 200 ÷ 200 + 679 = 22.8%.

HANDLING AND DEWATERING CHARACTERISTICS OF WASTE SLUDGE

Three important measures of these characteristics are: (1) the amount of mixing of lagoon contents required to secure a homogenous mixture of sludge solids and liquor in the centrifuge feed, (2) the percent solids in the centrifuge sludge cake, (3) the clarity of the centrate as measured by percent solids in the centrate, and (4) the capacity of the centrifuge to process the different sludges in terms of pounds per hour.

These characteristics with and without alum sludge are evaluated on the basis of two batches of sludge in the lagoons. One batch contained about 30% alum sludge and the other about 60% alum sludge.

The preliminary results are: (1) no serious adverse effects have been observed; (2) it appears that less stirring and recirculation of the lagoon contents are required to obtain a homogenous sludge feed to the centrifuge, which is an advantage; (3) the average total solids content in the centrifuge cake was 14.80% without alum sludge and was 14.93% with a partial load of alum sludge in the lagoon (this difference is not considered significant); and (4) the average total solids in the centrate decreased from 0.56% to 0.51% when a partial load of alum sludge was present. Again, the difference probably is not significant.

One important difference noted in the centrifuging operations was the fact that the yield increased from 600 to 800 pounds per hour for sewage sludge to about 900 pounds per hour for the alum sludge-sewage sludge mixture. The drying characteristics of the sludge containing WTP alum sludge are important, and have yet to be determined.

OVERALL WASTEWATER TREATMENT PLANT PERFORMANCE

As reported under Items 1, 2, and 3 above, the addition of alum sludge to the WWTP flow had a slight detrimental effect on primary settling; a slight beneficial effect on phosphorus removal; and had no apparent effect on COD removal.

However, the WWTP operators report that visual observations to date indicate that there may be some improvement in the settling characteristics of activated sludge during alum sludge discharge to the plant. There was an apparent reduction of scum problems in the secondary clarifier which allowed a higher mixed liquor suspended solids concentration to be carried in the activated sludge aerators. This could provide better BOD removal, greater ease of operation, and improved process control.* In primary effluent, the background BOD averaged 113 mg/l, and during alum sludge discharge averaged 114 mg/l which indicates no effect on BOD removal.

With addition of alum sludge to the WWTP, an increase in digester gas production beyond that generated by the increased load of volatile solids applied. The speculation is that this was due to easier mixing of digester contents.

No adverse effects on overall wastewater treatment plant performance were observed during the study. The greater solids load reduces time of solids in the digester, but no adverse effects have been detected to date.

CHARGES FOR PROCESSING ALUM SLUDGE

If alum sludge is accepted on a permanent basis at the WWTP, then there will be a need to arrive at a fair and equitable annual charge for receiving and processing the wastes.

*However, these effects could have been caused by something other than the addition of alum sludge and further observations are required.

It would seem that a minimum charge might be the incremental costs involved, and the maximum charge might be the pro-rata costs involved.

As previously discussed, the three principal effects of the alum sludge on wastewater treatment plant processing and costs are 0.25% increased plant flow; 23% more solids to digestion; and 29.5% more sludge solids to the lagoon, centrifuge, and disposal. It is assumed that the annual charge would include portions of the annual amortization of capital (construction) costs and interest in addition to a share of the annual O&M (operation and maintenance) costs.

On the basis of incremental cost (minimum charge), the annual charge would consist of the difference in cost between operation of the WWTP with and without the alum sludge load, plus the difference between the annual amortization costs for appropriate plant unit process capacities with and without the greater load.

On a pro-rata basis (maximum charge), the annual charge would be based on the construction and use of 0.25% of the primary and secondary liquid processing capacity; plus 18.6% of digester costs; plus 22.8% of the sludge lagooning, centrifuging, and disposal costs. The percent figures are preliminary and would be appropriately adjusted after additional test data are collected.

The actual capital expenditures and interest rates for plant construction should be used. If the records of actual construction cost are not broken down into unit costs for the various plant processes involved, then they can be accurately estimated as a percent of the actual total plant construction cost in accordance with current costs for constructing similar unit processes in other plants of the same capacity. Likewise, if WWTP cost accounting for annual O&M does not break costs down into figures for individual processes affected by the alum sludge load, then the percent of the total actual O&M costs assignable to the unit processes can be estimated rather accurately from published EPA cost curves derived from other plants of the same size. In sharing capital costs, Federal and State grants must be considered.

SECTION 6

COMPARISON OF RESULTS WITH THOSE FROM OTHER PROJECTS

OVERALL WASTEWATER TREATMENT PLANT PERFORMANCE

During this study no adverse effects on overall wastewater treatment plant performance were identified. In this regard the findings agree with those of Hsu and Pipes[1], and Salotto, Farrell, and Dean[2]. Zakrewski[3] reported a slight improvement in secondary settling of activated sludge.

EFFICIENCY OF PRIMARY SETTLING

The data from this project show a slight (but insignificant) decrease in the overall efficiency of primary settling during the addition of water treatment plant sludge, but operator observations indicate that the settling of waste activated sludge solids discharged to the primary basin may have improved with elimination of some scum problems in the secondary clarifier. The work of Zakrewski[3] confirms the negligible effect at low (less than 5%) water works sludge proportions, but at 8% WTP sludge shows increases in removals in primary sedimentation as follows:

SS	=	12.4%
BOD_5	=	19.9%
COD	=	26.2%

Salotto, Farrell, and Dean[2] reported improved settling of waste activated sludge in the primary tank with addition of alum sludge. At Tampe, Wilson, et al[4] report a 33% increase in suspended solids removal

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(1) Hsu, D.Y. & Pipes, W.O. The Effects of Aluminum Hydroxide on Primary Wastewater Treatment Process. Presented at the 27th Purdue Industrial Waste Conf., Purdue University, Lafayette, Ind. (May, 1972).

(2) Salotto, B.V., J.B. Farrell, and R.B. Dean. The Effect of Water-Utility Sludge on the Activated Sludge Process. JAWWA 65(6), p. 428. June, 1973.

(3) Zakrzewski, Dr. J. Effect of Water Work's Sludge on Wastewater Treatment. University of Warsaw.

(4) Wilson, T.E., R.E. Bizzarri, T. Burke, P.E. Langdon, Jr., and C.M. Lawson. Upgrading Primary Treatment With Chemicals and Water Treatment Sludge. JWPCF 47 (12), p. 2820. December, 1975.

at comparable flow conditions with addition of 30 to 60 mg/l of alum sludge and 0.7 mg/l of anionic polymer.

EFFICIENCY OF COD REMOVAL

During this study, the COD removals were unaffected by alum sludge addition. On the other hand, Zakrzewski[3] and Hsu and Pipes[1] reported increased COD removals from addition of alum sludge.

EFFICIENCY OF PHOSPHORUS REMOVAL

The results of this study show a slight increase in phosphorus removal during addition of water treatment plant sludge. Salotto, et al[2] reported no effect on phosphorus removal which they regarded as an unexpected result as they thought phosphorus removal might be improved.

INCREASED SLUDGE PRODUCTION

In this study the production of sludge was increased during addition of alum sludge. The reports of Salotto, et al[2], and Hsu and Pipes[1] are in agreement with this.

EFFECTS ON SLUDGE CHARACTERISTICS

The percent volatile solids in mixed sludge is reduced by the addition of alum sludge to the wastewater treatment plant. This is uniformly shown by the results of this study and by Salotto, et al[2] and Hsu and Pipes[1].

During this study it appeared that the handling and dewatering characteristics of waste sludge were not greatly changed except that: (1) the combined sludge was easier to mix, (2) the centrifuge yield increased from a range of 600 to 800 pounds per hour without alum sludge to 900 pounds per hour with alum sludge present, and (3) the drying time of mixed sludge was not determined.

METRIC CONVERSION FACTORS

Length

1 inch	=	2.540 centimeters
1 foot	=	0.3049 meters
1 statute mi	=	1.60935 kilometers
1 centimeter	=	0.39370 inches
1 meter	=	3.28 feet
1 kilometer	=	3280.83 feet = 0.62137 mile

Area

1 square centimeter	=	0.155 square inch
1 square meter	=	10.76 square feet
	=	1.196 square yards
1 hectate	=	2.47 acres
1 square kilometer	=	0.386 square mile
1 square inch	=	6.45 square centimeters
1 square foot	=	0.0939 square meter
1 square yard	=	0.836 square meter
1 acre	=	0.405 hectare
1 square mile	=	2.59 square kilometers

Volume

1 cu in	=	16.387 cu cm
1 cu ft	=	0.0283 cu m
1 cu yd	=	0.765 cu m
1 cu cm	=	0.0610 cu in
1 cu m	=	35.3 cu ft
	=	1.308 cu yds
1 liter	=	61.023378 cu in
	=	0.035314 cu ft
	=	0.264170 U.S. liquid gallon
	=	0.2201 imperial gallon
1 milliliter	=	0.0338 liquid ounce
1 U.S. liquid ounce	=	29.57 milliliters
1 U.S. liquid quart	=	0.946 liter
1 U.S. liquid gallon	=	3.785 liters

Weight

1 gram	=	15.43 grains
	=	0.0353 avoirdupois ounce
1 kilogram	=	2.205 avoirdupois pounds

METRIC CONVERSION FACTORS
(continued)

Weight (continued)

1 metric ton	=	0.984 gross or long ton
	=	1.102 net or short tons
1 avoirdupois ounce	=	28.35 grams
1 avoirdupois pound	=	0.4536 kilogram

Flow

1 mgd	=	1.547 cfs	=	43.8 liters per second
1 cfs	=	28.32 Lps		